esi® Engineering Bulletin

Electro Scientific Industries

7524 S. W. MACADAM AVE. • PORTLAND 19, OREGON

BRIDGES AND ACCESSORIES

no. 8

FEBRUARY 1960

REPLACES JANUARY 1958

DETERMINING THE EFFECTIVE JUNCTION AREA OF DIODES

ESI Wishes to express sincere thanks to the University of Illinois and Mr. T. A. Murrell, Associate Professor of Electrical Engineering at the university, for the information presented in this paper on the measurement of effective junction area of diodes.

The ESI Model 250 Series Impedance Bridge with the Model 855-A1 Amplifier Oscillator have been utilized by the Transistor Laboratory of the University of Illinois for determining the effective area of P-N type junctions. Figure 1 shows the basic circuit used. The ESI instruments were specifically selected because:

1. The Model 250 Bridge is the only universal bridge available with external terminals to which both A.C. and D. C. voltage can conveniently be applied simultaneously. A recommended generator-to-bridge coupling connector for use in this experiment is shown in Figure 2.

2. The Model 855-A1 Amplifier-Oscillator has adjustable A.C. generator voltage. During this experiment the A. C. voltage across the diode must be kept within a 0.1 to 0.2 volt range.

3. The D-Q range of the bridge can be extended conveniently. Junctions with low back resistance fall out of the D-Q range and it becomes necessary to measure parallel resistance (Rp) and capacitance (Cp) rather than the series values.

4. The bridge affords extremely high resolution in the low capacitance range.

5. The Model 855-A1 null amplifier has ample sensitivity for good null detection even with the limited A. C. generator voltage.

Junctions to be measured are connected directly to the capacitance ("C") terminals on the bridge. The Model 855-A1 amplifier-Oscillator is energized and its output is adjusted so that 0.2 volts appears across the junction. With a VTVM attached to the diode, D. C. voltage is applied to the junction in the reverse direction. The VTVM reading will rise rapidly as the D. C. voltage is increased if the voltage appears across the junction in the reverse direction. Should this voltage rise slowly, the polarity of the D.C. supply should be reversed.

Litho in U.S.A.

The Zener current point of the junction is then found by increasing the value of the D.C. applied voltage until a null pattern can no longer be obtained on the Model 855-A1 null indicator. At the Zener current point the junction breaks down electrically.

Before proceeding further, it would be well to take note of three precautionary measures:

1. Because the junction is in its break-down region at the Zener current point, permanent damage to the junction can result if Zener current voltage or greater is applied to the junction for extended periods of time.

2. Once the D.C. voltage has been applied to the junction, the bridge multiplier arms should not be changed. Referring to Figure 1, R1 is the main current limiting resistance in the circuit and a decrease of this resistance would cause a major increase in the voltage appearing across the junction.

3. To prevent measurement errors, the VTVM should always be removed when readings are being taken of the junction's capacitance. The impedance of the VTVM will have a substantial effect on the balance of the bridge.

The experiment proceeds as follows:

1. With the junction in place and the proper A.C. voltage applied, the D.C. voltage is increased until the Zener current point is reached. Reduce the D.C. voltage slightly and record this voltage and the measured capacitance.

2. Continue to decrease the D. C. voltage in small incremental steps recording the voltage and capacitance at each step.

3. Plot the voltage as ordinate and the measured capacitance as abscissa on log-log paper. At the lower voltage points the curve will tend to depart from a straight line. This departure is equal to the built-in voltage of the junction, thus this voltage can be easily approximated.

4. After approximating the built-in voltage, the experimental points should be corrected and replotted. The resultant curve should follow the equation

$$V = K C^{-M} \qquad \text{Equation (1)}$$

Two convenient voltage and two corresponding capacitance points should be selected as V_1 , V_2 and C_1, C_2 from the corrected curve. Placing these values in equation (2), the slope of the curve can be determined.

$$M = \frac{\log V_2 - \log V_1}{\log C_2 - \log C_1} \qquad \text{Equation (2)}$$

The (M) value varies according to the contact area of the junction and indicates if the junction has been grown or fused. In grown junctions this area is rectangular in shape and in fused junctions this surface is dished shape, similar to the bottom of a soup bowl. (M) is approximately 3 for grown junctions and 2.5 for fused ones.

After determining the type of junction, the cross sectional junction area can be computed by the theoretical equation (3). The voltage (V_T) and capacitance (C) used in these equations should be the values measured at the junction's Zener current point. These values are used because it has been found that at the Zener current point the cross section area has a known field (E_M) of 250,000 volts per square centimeter.

$$A = \frac{K_1 \ (V_T) \ (C)}{E_M} \qquad \text{Equation (3)}$$

A = Effective Junction Area

K_1 = 1.06 for grown Germanium Junctions

K_1 = 1.41 for fused Germanium Junctions

K_1 = 1.87 for fused Silicon Junctions

Additional calculations such as the effective width of the junction can be made if desired. The equation for these calculations is:

$$W = K' \frac{A}{C} = K_2 \ V_T \ 10^{-6} \qquad \text{Equation (4)}$$

W = Width of Space Charge Region

K_2 = 6.1 for grown Germanium Junctions

K_2 = 8 for fused Germanium Junctions

K_2 = 8 for fused Silicon Junctions

It was previously noted that the junctions which exhibited low resistance can not be measured by the method described above. Measurements of C_p and R_p can however be made by modifying the circuitry as shown in Figure 3. The major changes in this circuit include revising the method of applying reverse voltage to the diode, and with the D-Q dial set at zero, a calibrated potentiometer is placed across the standard capacitor. The system of applying reverse voltage must be changed because of the additional shunt path introducted by the calibrated potentiometer. It has been found that with this arrangement it is convenient to shunt each junction with approximately 2 megohms to keep the external "D" potentiometer setting for balance fairly uniform for different junctions. This system gives an erroneous "D" reading, but the "D" measurement is not utilized in any of the above calculations and has no importance in this experiment. Additional calculations of effective junction area and width can be computed as before.

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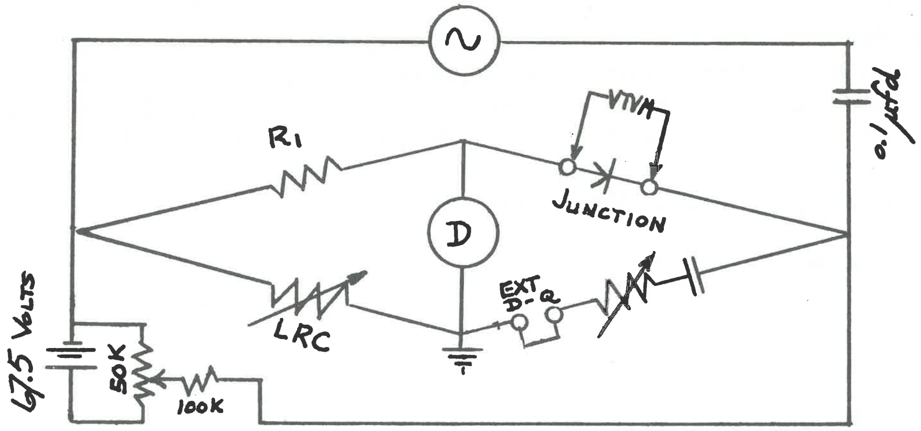
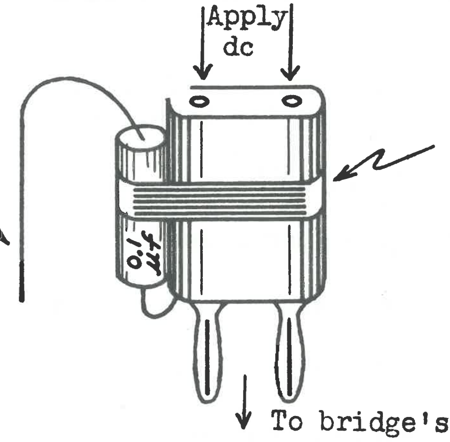


Figure 1. Bridge circuit used to determine the effective junction area of diodes. In the experiment, ESI Model 250-C1 Bridge is used.

Apply dc

Clip to swing lug on Model 855-A1 Oscillator Amplifier

Tape plug & capacitor together



To bridge's **EXT.** GEN. terminals

Figure 2. Recommended generator-to-bridge coupling connector used in the experiment.

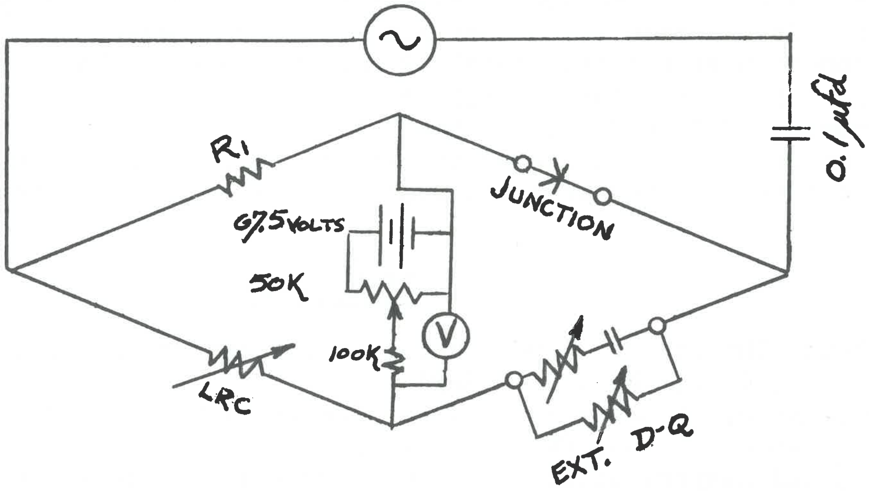


Figure 3. Schematic diagram of bridge circuit used for junctions having low back resistances.